Course Name: Nanotechnology
(Nanophotonics)
Course Code: MPE471
Final Exam.
BME Program
Level 400
Exam Date: 29-12- 2019
Allowed Time: 120 Minutes

*Attempt all questions. Assume any missed data.*

*Full mark is 50. The exam is in 3 pages.*

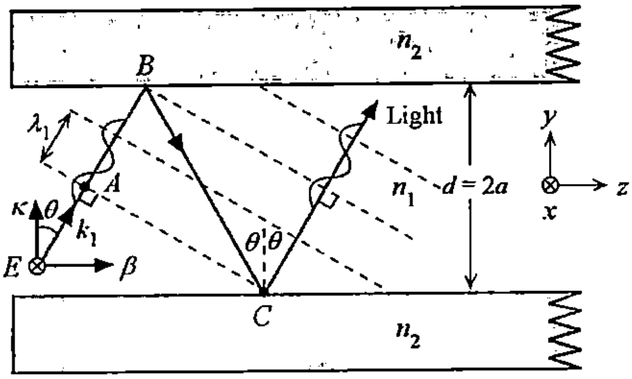



**Figure 1**

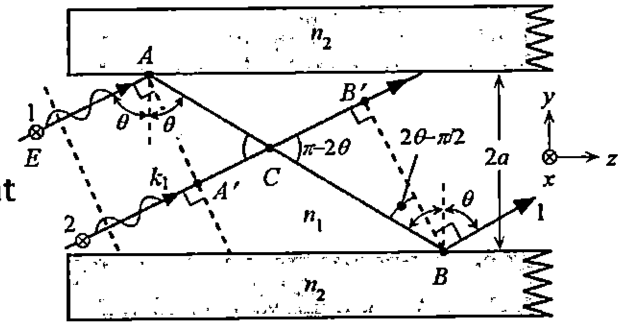
## Question No. 1 [20 Marks]

A light ray traveling in the guide must interfere constructively with itself to propagate successfully. Otherwise destructive interference will destroy the wave. $E$ is parallel to $x$. ($\lambda_1$ and $k_1$ are the wavelength and the propagation constant inside the core medium $n_1$ i.e. $\lambda_1 = \lambda/n_1$).

(a) Prove that only certain angles are allowed. Each allowed angle represents a mode of propagation; i.e. **prove the waveguide condition**:

$$\left[\frac{2\pi n_1(2a)}{\lambda}\right]\cos\theta_m - \varphi_m = m\pi$$

(b) Consider the two parallel rays 1 and 2 in Figure 2.




**Show that** when they meet at point **C** at a distance **y** above the guide center, the phase difference is:

$$\emptyset_m = k_1 2(a - y)\cos\theta_m - \varphi_m$$

**Figure 2**

(c) Using the waveguide condition **show that:**

$$\emptyset_m = \emptyset_m(y) = m\pi - \frac{y}{a}(m\pi + \varphi_m)$$

(d) The two waves interfering at C can be most simply and conveniently represented as:

$$E(y) = A\cos(\omega t) + A\cos(\omega t + \emptyset_m(y))$$

Hence **find the amplitude of the field variation along $y$,** across the guide. What is your conclusion? Draw the electric field patterns of first three modes of traveling wave along guide.

## Question No. 2 [6 Marks]

A particular HeNe laser beam at 633 nm has a spot size of 0.8 mm. Assuming a Gaussian beam, what is the divergence of the beam? What are its Rayleigh range and beam width at 10 m?

## Question No. 3 [12 Marks]

(a) A comparison of two step index fibers, one $SMF$ and the other $MMF$ shows that the $SMF$ has a core diameter of 9 $\mu m$ but a cladding diameter of 125 $\mu m$, while the $MMF$ has a core diameter of 100 $\mu m$ but a cladding diameter that is the same 125 $\mu m$. Discuss why the manufacturer has chosen these values.

(b) Compare between Intermodal dispersion, Intramodal dispersion through optical fibers. How to overcome each type of them?

## Question No. 4 [12 Marks]

(1) When an unpolarized light is incident on a polarizer, ....................................... will pass.

- (a) only the component parallel to the Transmission Axis.
- (b) only the component normal to the Transmission Axis.
- (c) all parallel and normal components.
- (d) no electric field.

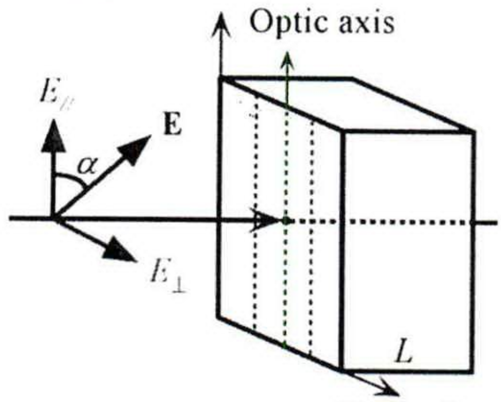



**Figure 3**

(2) In figure 3, which component will travel faster if the retarder plate is made from a positive crystal?

- (a) $E_{\parallel}$
- (b) $E_{\perp}$
- (c) *Both components will travel with the same speed*

(3) In figure 3, which component will travel faster if the retarder plate is made from a negative crystal?

- (a) $E_{\parallel}$
- (b) $E_{\perp}$

(c) *Both components will travel with the same speed*

(4) In figure.3, the phase difference between the two components depends on.......................

(a) The crystal length.
(b) The crystal type.
(c) The wavelength of incident light.
(d) All the above.

(5) In figure 3, if $\alpha = 45° \; and$ the phase difference $(\Delta\varphi)$ between the two electric field components is $\pi/_2$ , the polarization of the output field is ......................

(a) Linear.
(b) Right circular.
(c) Left circular.
(d) Elliptical.

(6) In figure 3, if $\alpha = 55° \; and$ the phase difference $(\Delta\varphi)$ between the two electric field components is $\pi/_2$ ,the polarization of the output field is ......................

(a) Linear.
(b) Right circular.
(c) Left circular.
(d) Elliptical.

(7) If $\alpha = 55° \; and$ the phase difference $(\Delta\varphi)$ between the two electric field components is, the polarization of the output field is ......................

(a) Linear.
(b) Right circular.
(c) Left circular.
(d) Elliptical.

(8) When the incident light on anisotropic crystal is in a direction parallel to its optical axis, the crystal will behave as ......................

(a) Isotropic crystal.
(b) Fully anisotropic crystal.
(c) Transverse anisotropic crystal.

# Formula Sheet

Gaussian beam radius; $w(z) = w_0[1 + \left(\frac{z}{z_0}\right)^2]^{\frac{1}{2}}$

Rayleigh range; $z_0 = \frac{\pi w_0^2}{\lambda}$

Divergence angle; $\theta = \frac{\lambda}{\pi w_0}$

V-number; $V = \frac{2\pi a}{\lambda}(n_1^2 - n_2^2)^{1/2}$